Astronomy 330

This class (Lecture 18):
Origin of Intelligence

Next Class:
Biological Evolution

HW #7 due Wednesday.
Presentations don't forget.

Music: *Intelligent Guy*– Butthole Surfers

THE FLAKE EQUATION:

FRACTION OF PEOPLE WHO IMAGINE AN ALIEN ENCOUNTER BECAUSE THEY'RE CRAZY OR WANT TO FEEL SPECIAL

PROBABILITY THAT THEY'LL TELL SOMEONE

AVERAGE NUMBER OF PEOPLE EACH FRIEND TELLS THIS "FIRSTHAND" ACCOUNT

FRACTION OF PEOPLE WITH THE MEANS AND MOTIVATION TO SHARE THE STORY WITH A WIDER AUDIENCE (BLOGS, FORUMS, REPORTERS)

$$P = W_P \times (C_R + M_I) \times T_K \times F_o \times F_I \times D_r \times A_v \approx 100,000$$

$(7,000,000,000)$ $(\frac{1}{10,000})$ $(\frac{1}{10,000})$ $(\frac{1}{10})$ (10) (10) $(\%_{10})$ $(\frac{1}{100})$

WORLD POPULATION

FRACTION OF PEOPLE WHO MISINTERPRET A PHYSICAL OR PHYSIOLOGICAL EXPERIENCE AS AN ALIEN SIGHTING

AVERAGE NUMBER OF PEOPLE THEY TELL

PROBABILITY THAT ANY DETAILS NOT FITTING THE NARRATIVE WILL BE REVISED OR FORGOTTEN IN RETELLING

EVEN WITH CONSERVATIVE GUESSES FOR THE VALUES OF THE VARIABLES, THIS SUGGESTS THERE MUST BE A *HUGE* NUMBER OF CREDIBLE-SOUNDING ALIEN SIGHTINGS OUT THERE, AVAILABLE TO ANYONE WHO WANTS TO BELIEVE!

http://xkcd.com/718/

Question

How was your Spring Break?

a) Good
b) Bad
c) Better than you thought it would be.
d) Worse than you thought it would be.
e) You missed me horribly. (xoxoxoxo :p)

Question

How is the class going so far?

a) Perfect
b) Good.
c) Bad.
d) Okay.
e) I don't want to answer this on iclicker.

Exam 2

- Exam 2 is coming up– April 8th!
  - Week from Thursday
- Will be similar to Exam 1.
- Cover from last exam up to Thursday's lecture.
- Again, 1 sheet of notes will be allowed.

Question

How many multiple choice questions do you want on Exam 2 (Exam 1 was 35)?

a) 28
b) 30
c) 35
d) 38
e) 40

Paper Rough Draft

- Worth 1% of your grade, but really worth more.
- Due on or before April 14th! (Hard date!)
  - Beginning of discussion class, else considered late.
- Should pretty much be the final paper.
- Will be looking for scope, ease-of-read, scientific reasoning, **proper citation**, and general style.
- 6 to 8 pages double-spaced 12-point font, not including references.

Paper Rough Draft

- *Mars is a planet without an overzealous monkey population (Holt et al. 2000; James & Mann 2006; Walker 2007; Wikipedia: Mars).*
  - *I expect to see a few refs per page!*

- Holt, W., Smith, E., Rowe, T., & Jones, A. B. 2000, The Astronomical Almanac for the Year 1994, Vol. 2 (2nd ed.; Washington, DC: GPO)
- Smith, A. B., Thomas, J. R., Major, W., & Peebles, P. J. E. 2006, Astrophysics Journal, 450, 12
- Wikipedia: Mars, http://en.wikipedia.org/wiki/Mars, Accessed: March 25, 2010, Updated: March 24, 2010

Outline

- Two types of cell life: Eukaryotes and Prokaryotes.
- All life can be divided into 3 types:
  - Bacteria
  - Archaea
  - Eukarya
- Genetic diversity of life…

Drake Equation

Frank Drake
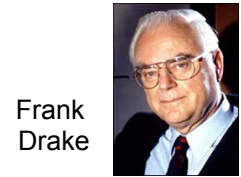
That's 5.9 x ? life systems/decade

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$

# of advanced civilizations we can contact in our Galaxy today	Star formation rate	Fraction of stars with planets	# of Earthlike planets per system	Fraction on which life arises	Fraction that evolve intelligence	Fraction that commun-icate	Lifetime of advanced civilizations
9 stars/ yr	0.29 systems/ star	1.03 x 0.22 = 0.23 planets/ system	? life/ planet	intel./ life	comm./ intel.	yrs/ comm.	

Evolution of Intelligence

- What is intelligence?
- "The ability to model the world, including the organism's own self" is a workable definition.
  - A spectrum of ability
- Crucial development for the full spectrum of intelligence is the diversity of life on Earth.
- Intelligence is not a requirement of life.

http://www.amonline.net.au/insects/images/site/insect1.jpg

Evolution of Intelligence

- First, we will examine the diversity of life; the fossil record shows a huge diversity with time.
- Organisms range from bacteria to humans.
- 1.8×10^6 known species
  - Insects account for most (1.0×10^6)
  - Estimated that only 10% are known.
  - Bacteria are hard to classify– only 7700 species so far.

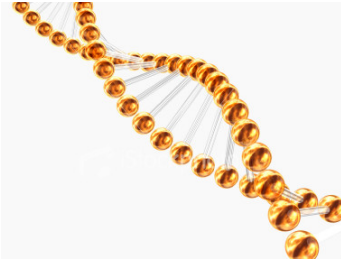http://www.amonline.net.au/insects/images/site/insect1.jpg

Evolution of Intelligence

- Remember that all of these organisms use nearly identical genetic codes, so life descended from a common ancestor.
- Primary challenge of biology is to explain how life from a single type of organism, diversified so much.
- Evolution is the primary concept.

Life

If we took all the biomass of all the animals, and all the biomass of all the viruses, bacteria, protozoa, and fungi– who weighs more?

A) Whales, elephants, etc.
B) Microscopic life

Around 90% of all biomass on the Earth is in the smallest and simplest lifeforms.

Bacteria

- 40 million bacterial cells in a gram of soil
- 1 million bacterial cells in a milliliter of fresh water
- Something like five nonillion (5×10^{30}) bacteria in the world.
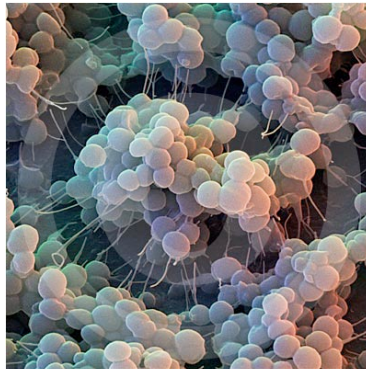
Staph bacteria
http://www.scharfphoto.com/fine_art_prints/archives/000608.php

You or not you?

- There is more non-you cells in your body than you-cells in your body!
  - You are outnumbered 10 to 1!
  - Mostly on your skin and in your digestive track

Bacteria under a toe-nail

http://news.nationalgeographic.com/news/2007/02/070206-skin-microbes.html

Question

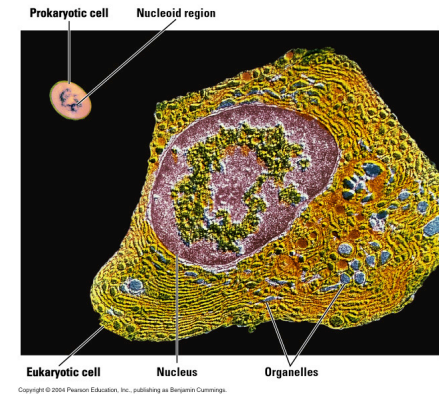What is a fair definition of intelligence?

a) Able to get an A on the midterm.

b) Able to develop a new iphone application

c) Leslie

d) The ability to model the world, including the organism's own self

e) The ability to model the world into food or threat

Classification of Life

1. Prokaryotes
   - No cell nucleus– DNA floating around
   - Always single-cell creatures like bacterium
   - Came first
   - Outnumber and outweigh the second class (eukaryotes)

Prokaryotic cell   Nucleoid region

Eukaryotic cell   Nucleus   Organelles

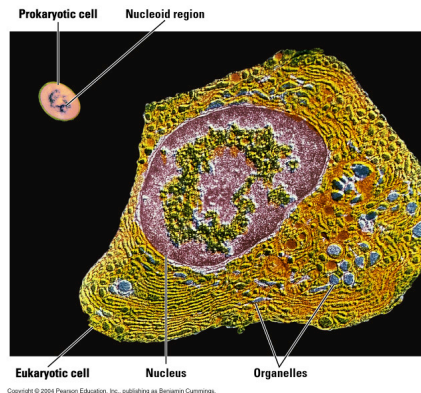Copyright © 2004 Pearson Education, Inc., publishing as Benjamin Cummings.

Classification of Life

2. Eukaryotes
   - Have a cell nucleus, a membrane to protect the DNA
   - Basis of all multi-cell creatures
   - Also some single-cell creatures like amoebas.
   - DNA arranged into chromosomes in nucleus– 23 pairs for humans.

Prokaryotic cell   Nucleoid region

Eukaryotic cell   Nucleus   Organelles

Copyright © 2004 Pearson Education, Inc., publishing as Benjamin Cummings.

Prokaryotes

Divided into 2 domains:

1. Eubacteria or "true" bacteria

2. Archaea
   - 20% of the world's biomass.
   - Thought to be the oldest surviving organisms.
   - Often found in harsh environments: hot springs, undersea vents, salty seashores, etc, which were probably more common on the early Earth.
   - Some evidence that ancient organisms were heat-lovers (maybe)
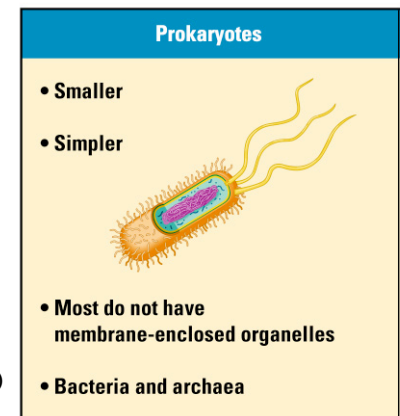
Carl Woese here at UIUC, discovered Archaea scheme.

Prokaryotes

- Smaller

- Simpler

- Most do not have membrane-enclosed organelles

- Bacteria and archaea

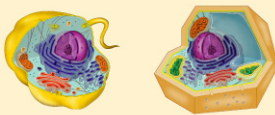Copyright © 2004 Pearson Education, Inc., publishing as Benjamin Cummings.

Eukaryotes

- All animals, plants, and fungi.

Eukaryotes
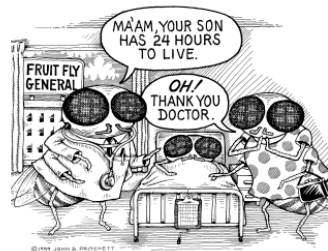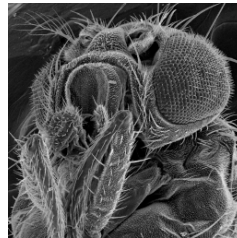
- Larger
- More complex
- Membrane-enclosed organelles
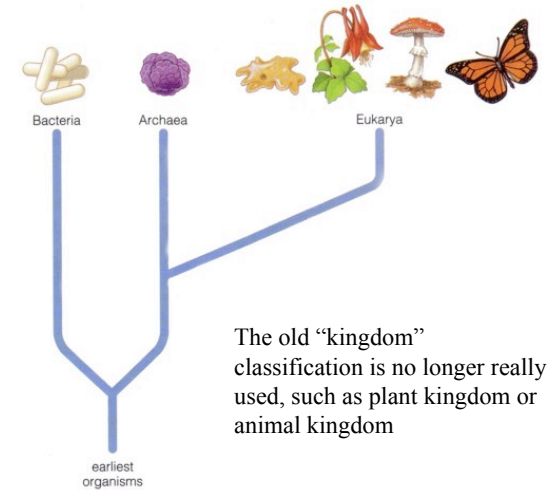- Protists, plants, fungi, animals

3 Domains of Life

- Genetically speaking, Archaea and Eukarya are more similar to one another than are Bacteria and Archaea

- Implies that Archaea and Bacteria split and then all Eukarya split from Archaea

- A major implication for the evolution of life on Earth

Bacteria   Archaea   Eukarya

earliest organisms

The old "kingdom" classification is no longer really used, such as plant kingdom or animal kingdom

Genetic Relations

- This is a major change from the old methods of assigning groups based on outward form and anatomy.
- Instead based on studies of the genetic code.
- Surprise: Human and chimpanzees share about 99% of the same DNA, and about 97% with mice.
- Surprise: 2 species of fruit fly look very much alike, but only share about 25%. Some of this differences is due to "*junk*" DNA.

MA'AM, YOUR SON HAS 24 HOURS TO LIVE.

FRUIT FLY GENERAL

OH! THANK YOU DOCTOR.

http://www.uglybug.org/index00.shtml

http://www.pritchettcartoons.com/fruitfly.htm

Question

What type of life is more closely related to us?

a) Archaea
b) Eubacteria
c) True Bacteria
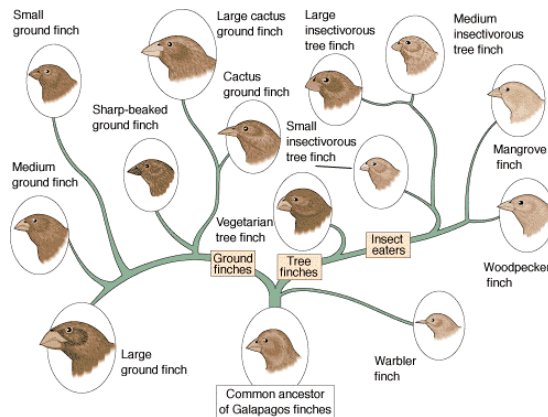d) Martians

Changes in Bio-Systems
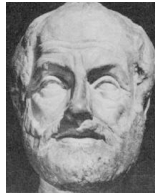
- Today's view: evolution is the most important and unifying property of life.
- Anaximander (c. 610-547 BC): life arose in water and gradually became more complex
- Empedocles (c. 492-432 BC): survival of the fittest (but, "*a good idea stated within an insufficient theoretical frame loses its explanatory power and is forgotten*" by Hans Reichenbach)
- Aristotle (384-322 BC): species are fixed and independent of each other → evolution discarded for 2000 years
- Fossil record: slowly broke down the Aristotelian theory

For the Species Survival

1. Population with varied inherited traits
2. Elimination of individuals with certain traits
3. Reproduction of survivors
4. Increasing frequency of traits that enhance survival and reproductive success

Copyright © 2001 by Benjamin Cummings, an imprint of Addison Wesley.

- Darwin (1809-1882) & Malthus (1766-1834):
  - Populations can grow faster than food sources can support them.
  - Creates a struggle for survival that can wipe out competitors.
  - Individual variations has advantages or disadvantages in the struggle for survival
  - Natural selection can create unequal reproductive success
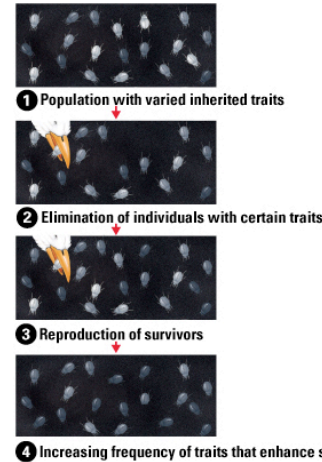
Filling the Niche with Finch

- Other Evidence:
  - Adapted species in the Galápagos Islands, in particular finches
  - Artificial breeding of house/farm animals and vegetables
- DNA is really the mechanism of natural selection, but evolution requires both heredity and environment

Small ground finch
Large cactus ground finch
Large insectivorous tree finch
Medium insectivorous tree finch
Cactus ground finch
Sharp-beaked ground finch
Small insectivorous tree finch
Mangrove finch
Medium ground finch
Vegetarian tree finch
Ground finches
Tree finches
Insect eaters
Woodpecker finch
Large ground finch
Warbler finch
Common ancestor of Galapagos finches

Mutant Sex

- Mutations from changes in the bases of DNA.
- Usually copying errors, but also radiation–radioactivity, cosmic rays, chemical agents, or UV light.
- About 3 mutations per person per generation.
- Most mutations are neutral, changes in the *junk* DNA.
- Why is sex important to this class?
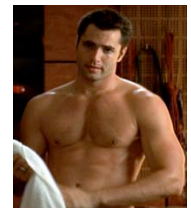
http://www.mutantx.net/features/press_vw_sexy.html

Mutant Sex

- Sexual reproduction leads to greater genetic diversity– a difference between prokaryotes and eukaryotes?
- Asexual reproduction does not allow 2 new and beneficial mutations to combine.
- Blackberries have not changed much in 10 millions years, but sexual plants have produced: raspberries, thimbleberries, cloudberries, dewberries, etc.
- Sex is useful in the process, but the mutations are still key.

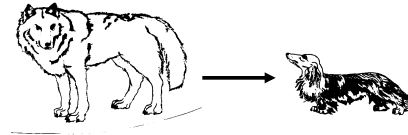http://www.alcasoft.com/arkansas/blackberry.html

Does it take a long time?

Cabbage, kale, kohlrabi, brussels sprouts, cauliflower and broccoli have same common ancestor– wild mustard. All bred by humans on a very short time scale.

This is selective breeding, but still the potential is in the DNA.

Or domestic lap dogs from wolves in about 5000 years.

Question

Sex in space, or on Earth, is important because

a) sex, although fun, also stimulates gene mutations.

b) it allows the genetic material of the better organisms to survive.

c) mutations can only occur in sexual reproduction.

d) it leads to greater genetic diversity and an increase of positive mutations in the offspring.

e) it allows animals to "cross-fertilize" across species
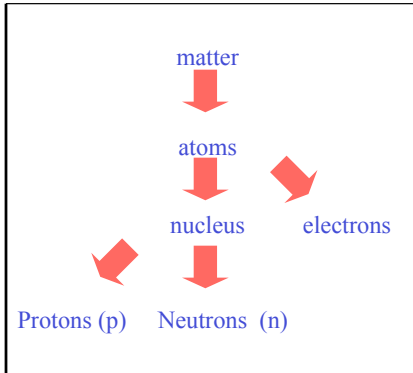
Comparing Ages

- Important to understand history of Earth life is the ability to age different components
- Can be difficult
- Radioactive dating….
  - ^{14}C for the last 60,000 years
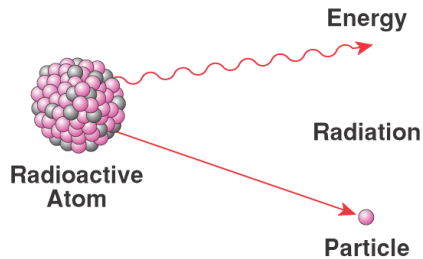 - ^{40}K and ^{235}U for 100's of millions of years

Radioactive Dating

Recall:

- Most atomic nuclei stable
- But some nuclei are *unstable*,
  - ⇒ *decay* to new nucleus **"radioactive"**

The Law of Radioactive Decay

As radioactive "parent" decays, the number of decay product or "daughters" increases

Decay is a good "clock"
- Each radioactive species has different "tick"
- Rate= "half-life"
- Exponential decay from original population of n_0

Decay Rule
Start out with N parents, 0 daughters

| Time t since start	# parents	# daughters
0	N	0
$t_{1/2}$	½ N = half as much	½ N have appeared
$2t_{1/2}$	¼ N = half again as much	¾ N
$3t_{1/2}$	1/8 N	7/8 N
$30t_{1/2}$	About N/10^9	99.9999999% N

Radioactive Decay Examples

http://www.colorado.edu/physics/2000/isotopes/radioactive_decay3.html
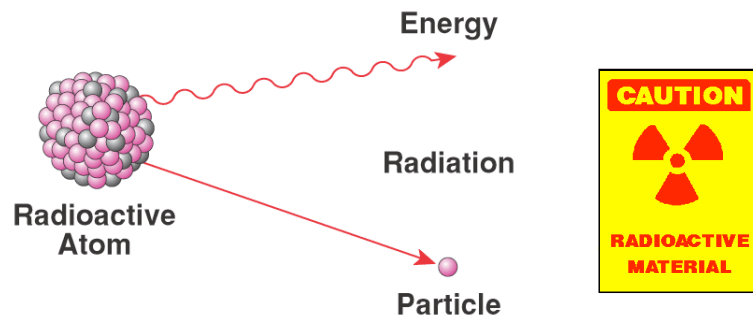
Carbon-14

- Cosmic rays from space are constantly hitting the Earth.
- React with ^{14}N in atmosphere to create ^{14}C.
- Decays back to ^{14}N with half life of 5730 years.
- But, there is an equilibrium in abundance
- In atmosphere, the ^{14}C is mostly in $^{14}CO^2$.
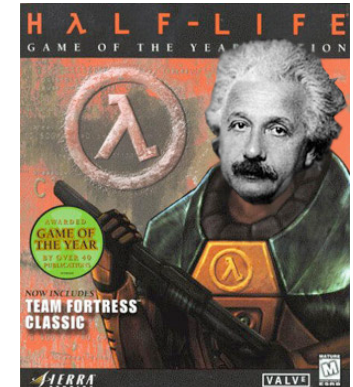
http://bbspot.com/Images/News_Features/2003/12/half-life.jpg

Carbon-14

- Plants take in $^{14}CO_2$ with the $^{12}CO_2$ and other animals eat the plants.
- So, every living creature has a equilibrium ratio of $^{14}CO_2/^{12}CO_2$.
- When the organism dies, the ^{14}C decays to ^{14}N. By measuring how much ^{14}C remains, you can date the fossil.
- This works well to about 60,000 years.
  - Viking remains in Newfoundland– 500 yrs before Columbus.
 - Shroud of Turin to 1330 AD

http://web.mit.edu/smcguire/www/newfoundland/newf16.html

Dating Rocks

- First you ask them out?
- No, you need a radioactive decay that has a longer half-life than ^{14}C.
- Potassium-argon
  - ^{40}K decays to ^{40}Ar with a 1200 Myr half-life.
- Uranium-lead
  - ^{235}U to ^{207}Pb with 700 Myr half-life.
- But these only work with volcanic layers.
- So, the ages of fossils are interpolated from ages of volcanic layers above and below them.
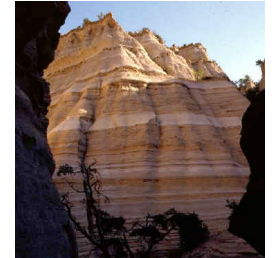
Era	Period	Myr Ago	Life Forms	Events
Cenozoic	Quaternary	2	H. Sapiens	Ice ages
	Tertiary	65	Primates	Extinction of Dinosaurs
Mesozoic	Cretaceous	136	Birds	S. Atlantic open to 1900 miles
	Jurassic	190		N. Atlantic open to 600 miles
	Triassic	225	Mammals	Continental drift
Paleozoic	Permian	280	Reptiles	Pangaea breaks up
	Carboniferous	345	Amphibians	Formation of coal
	Devonian	395	Insects	
	Silurian	430	Land Plants	
	Ordovician	500	Fish	
	Cambrian	543	Trilobites	
Precambrian		545	Small Shelly Fossils	
		580	Ediacarans	
		600-800	Multicellular life	Snowball Earth episodes

Increase of Complexity

- Last table showed only the last 800 Myrs.
- The more complex and intelligent organisms appeared towards the end.
- For many years it was thought that life originated in the Cambrian era, then Precambrian fossils were found.
- Then, it was realized that there were single-celled fossils that required microscopes.

Myr Ago	Era	Event
Now	Cenozoic	
	Mesozoic	
	Paleozoic	Macroscopic life/Snowball Earth
	Precambrian	
1000		Worm tracks
		Multicellular algae
		Eukaryotes certain
		Sexual reproduction
2000		Eukaryotes possible
	Protozoic	Oxygen-rich atmosphere
		Snowball Earth
		Formation of continents
3000	Archean	Life begins?
4000		Formation of Oceans
		Bombardment decreases
		Frequent impacts
	Hadean	Earth formed

Concepts

- As prokaryotes are simpler than eukaryotes, we expect them to exist first.
- Identifying fossil prokaryotes is difficult: they're tiny!
- But there is enough evidence that before 1500-2000 Myrs ago there are only prokaryotes fossils.
- Note: the oldest fossils (3800 Myrs ago) are under some dispute, but the 2800 Myr old fossils are universally accepted.
- All of the macroscopic life only arose in the last 600 Myrs– 1/6th of the history of life on Earth.

http://www.earth.ox.ac.uk/research/geobiology/geobiology.htm